TEXTURE AND TRIAXIAL STRESS IN Al AND Cu INTERCONNECTS STUDIED BY X-RAY MICRODIFFRACTION WITH SUBMICRON RESOLUTION

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The structural properties of thin film as well as bulk samples are critically determined by their mesoscale structure (i.e. the submicron to micron range structure of grain boundaries, dislocations, inclusions, voids,…) . The ability to measure with high accuracy local texture and triaxial stress variations is primary for the understanding of major scientific and technological issues such as failure in integrated circuit interconnects and deformation and grain growth during material synthesis.

For this purpose we have developed at the Advanced Light Source, a dedicated X-ray microdiffraction beamline combining white and monochromatic beam capabilities. By bending into plane ellipses a pair of Kirkpatrick-Baez flat mirrors, we were able to achieve a beam size of about 0.8 by 0.9 microns. A 4-crystal Ge or Si monochromator in front of the focussing mirrors can be moved in and out of the beam and allows the ability to be able to switch back and forth between white and monochromatic beam, whilst illuminating the same small spot on the sample.

The actual measurement technique consists of illuminating the sample with the submicron broad bandpass (white) beam and collecting the X-ray outgoing reflections using a large area (9 x 9 cm) CCD detector. The orientation and the full deviatoric (distortional) strain/stress tensor of the illuminated area are directly derived from the analysis of the resulting Laue patterns. The dilatational component of the strain is obtained by switching to monochromatic beam and making energy scans on selected reflections. The sample is mounted on a precise positioning stage that allows the sample to be scanned

This procedure has been successfully applied to the study of residual strain in passivated Al and Cu interconnect tests structures as well as in Cu blanket films. The evolution of the inter- and intragranular texture and strain has also been studied as a function of temperature. In situ electromigration experiments have been carried out on Al test structures. We found that the microstructure at submicron level in these materials is rather complex with grains divided into sub-grains and inter- as well as intra- granular variations of both strains and orientations, which could lead to some new insights on the understanding of failure in interconnects.

Key features of this new technique include high orientation and strain sensitivities, material phase sensitivity, non-destructive nature and the penetrating power of X-rays allowing the ability to probe buried samples. This technique offers a promising and unique alternative to back-scattering scanning electron microscopy/microdiffraction for the study of microstructure at submicron level in materials. Especially since electron scattering cannot be used for covered or passivated structures.